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A HIGH-EFFICIENCY PROCESS OF MOLDING MINIATURE CERAMICS

M. I. Timokhova[1] and L. I. Medvedeva[1]

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A highly efficient technology for molding miniature ceramics using static molding on automatic presses has been developed. The products have high accuracy of sizes and good physicomechanical and dielectric properties.

Contemporary engineering requires new miniature devices operating under microwave frequencies, which calls for the development of a highly efficient method for molding miniature ceramics with improved physicomechanical and dielectric characteristics.

To ensure the properties required, the following nonplastic materials were used: aluminum-oxide VK 94-1 and high-alumina VK 100-2 containing 99.7% Al_2O_3 and 0.3% MgO.

The standard technology for producing articles from these materials is hot injection molding. However, this method proved to be unacceptable for molding miniature articles, since it did not ensure high accuracy of sizes without additional mechanical treatment of fired articles (grinding and finishing). Furthermore, owing to the small sizes of articles, this method is extremely labor- and time-consuming regarding such technological operations as flash removal, burning temporary technological binder by means of pouring a highly dispersed mineral powder over the article, and removal of residual powder from the article surface after firing.

It is known that compression in metal molds allows for better precision of sizes (two classes higher than hot injection molding), is cost-effective, and makes it possible to fully mechanize and automate the molding process [1 – 3].

Having analyzed the existing molding methods and having produced prototype batches of some miniature ceramic products by hot injection molding, we selected the static compression method.

Articles developed included miniature disc-shaped plates of diameter 5.6 – 6.0 mm and 0.30 – 0.38 mm thick, waveguide windows of size 4.20 × 2.65 mm and height 0.258 – 0.260 mm, larger waveguide windows of sizes 15.0 × 10.0 × 0.525 and 19.5 × 12.5 × 0.4 mm, washers with a maximum outside diameter of 2.6 mm, inside diameter 1.8 mm, and height 1.0 mm, boards with several holes, ceramic parts shaped as plates with a circular or rectangular socket, plates with a collar around the perimeter, and rectangular and square frames. Altogether over 15 products were developed.

Ceramic products with two parallel flat sides (discs, rectangular plates, waveguide windows, washers) were the simplest with regard to the manufacturing technology. Molding was effected by punches with flat ends. Special attention was paid to correct pouring of molding powder into a mold and developing conditions for complete removal of excessive air from the powder during compression.

It is known that air pressed into a product produces stratification and increased porosity. To avoid the specified drawbacks, notches in the form of a grid 0.2 – 0.3 mm deep with spacing of 1.0 – 1.5 mm were deposited on the shaping surfaces of punches. Radial notches were deposited on washer-shaped articles. Such configuration of notches provides a free outlet for air, since the molding powder does not fully fill a groove formed by the notch and some unfilled space is left near the groove bottom, through which air is removed. It should be noted that molding mixtures did not stick to the shaping surface with notches, nor were there any tearing off of molded part surfaces. Appropriately deposited notches on punches always improve the molding process and cannot become a reason for defect formation.

Production of square and rectangular plates with a circular or rectangular socket on one side caused several difficulties in molding. The size of the smallest items of this group of articles was 6.5 × 6.5 mm with height 0.8 mm and socket diameter 3.2 × 0.3 mm. The size of the average parts was 19.2 × 6.5 mm, the height 1.5 mm, the socket size 4.0 × 6.7 × 0.6 mm, and the weight of articles 0.6 g. The size of the largest items was 31.0 × 13.0 × 1.8 mm with a rectangular socket. The permissible extent of imperfect flatness for the specified articles should not exceed 0.05 mm. Items with a socket molded in a mold with standard flat punches had substantial deformation due to the difference in the densities at the periphery of the item and in the socket. The density in-

[1] Remeko Company, Moscow, Russia.

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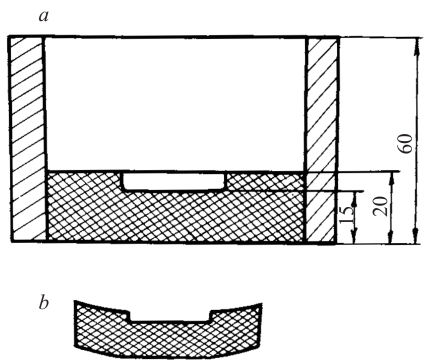

Fig. 1. A cross-section of an article with nonuniform height: *a*) ratio of thickness of a poured powder layer to thickness of molded layer; *b*) main type of deformation.

side the socket was 30 – 35% higher than the density at the periphery.

The sharp increase in density inside the socket is due to the fact that ceramic molding powders have poor fluidity at the molding pressures selected; consequently molding powder poured into a mold with the same height across the whole mold area cannot be redistributed inside the matrix space in accordance with the profile of the article molded; thus, a site of a higher pressure arises and causes the formation of a zone of higher density in the molded article. Nonuniform density causes high stresses in parts during their manufacture, especially in sintering, which leads to nonuniform shrinkage and warping (Fig. 1).

Accordingly, special molds have been developed with differentiated filling, i.e., with a floating punch, which made it possible to obtain a uniform density both at the periphery and inside the sockets of molded articles. This type of punch made it possible to produce articles in which imperfection of flatness after firing was normally equal to 0.01 – 0.03 mm and only occasionally to 0.04 mm. This group of articles did not undergo mechanical treatment before or after firing.

Plates sized 36 × 24 mm with a collar 0.9 mm high and a total height of 2.0 mm and frames sized 36 × 24 × 1.2 mm with a wall thickness of 2.0 mm were produced of material VK 100-2. These articles were molded with an allowance of 1.5 mm high, which was ground off after firing. The lateral walls of the plates and the frames after firing were rectangular and did not require mechanical treatment, whereas multiple attempts to mold frames by hot injection molding were unsuccessful due to substantial deformation.

In developing the molding technology for miniature articles, whose final thickness varies from 1 to 4 mm depending on the product, special attention was paid to selection of the composition of the technological binder, the method for molding powder preparation, and the ability of the powder to ensure the required accuracy and stability of size in the finished articles. Furthermore, molding powders had to possess high friability, which is required for a fast and continuous feed of powder portions into a mold to comply with the high efficiency of automatic molding machines.

A polyvinyl-glycerin binder was selected as a plastifier for molding powders VK 94-1 and VK 100-2. Depending on material molded and the type of the product, the content of the technological binder was 7 – 9 %.

The granulometric composition of the molding powder varies within the limits from 100 to 700 μm. The powder were prepared by briquetting.

In choosing a method for powder preparation, comparative tests of the moldability of aluminooxide material VK 94-1 prepared by drying in a spray drier or by briquetting were carried out The tests showed that in order to obtain the same degree of mechanical strength in molded products, the powder prepared by spray drying requires higher molding pressure (by more than 50%). The product molded from this powder had lower density; accordingly, the fire shrinkage coefficient grew from 1.13 to 1.18. The rigid surface of granules resulted in an increased wear of molds. The experiments established the advisability of using powder prepared by briquetting. Articles molded from such powder have good homogeneity of structure and high density.

Molding powders prepared by briquetting, due to their higher air conductivity, make its possible to apply a higher molding pressure, which is essential for the production of miniature ceramics. The briquette-molding pressure was lower that the pressure of molding products. Otherwise excessively rigid granules would lower the product plasticity, which would result in poorer structural homogeneity of molded products and impair the physicomechanical and dielectric properties of finished articles.

Molding of articles was carried out at a specific pressure of 120 – 200 MPa depending on the product configuration and the composition of material molded. The articles had sufficient strength both for mechanical removal from molds (without any deformation) and for further technological operations.

The optimum selected values of specific molding pressure made it possible to fire ceramic articles without preliminary drying. Molded articles were placed on alundum supports in several rows immediately after molding, one strictly on top of another, and electrocorundum was poured over each row. A permissible height for such items was 40 – 50 rows. The articles were fired in a PGT-5 gas tunnel furnace.

Automatic molding of articles was carried out on two-position automatic presses-292 and on single-position automatic presses 1512 and 1513 (Fig. 2). The presses implemented the following operations: filling a mold with molding powder from a hopper; molding an article, removing the article from the mold, and pushing the molded article onto a tray.

Selection of the number of machine strokes for compression of a particular article was based on the time it took to fill the mold volume and on the moldability of powder. The more complex an article, the fewer the number of strokes. Molding on a two position press-292 was carried out at a rate

Fig. 2. Automatic molding press.

of 40 strokes per minute, and the output per shift was 20 thousand pieces. The molding rate of presses 1512 and 1513 was equal to 20 strokes per minute, the output was 7 – 8 thousand pieces per shift.

The specified automatic presses are equipped with cyclograms, which makes it possible to easily correct the molding regime and to modify the molding schedule of a press when changing from one product to another.

The developments of a highly efficient process for molding miniature ceramics made it possible to organize a production division for 20 million units per annum.

In industrial production in this division great attention was paid to experimental choice of the mold material with regard to its wear resistance. Materials tasted includes steel of grades Kh12, Kh12M, 40Kh, Kh12F1, and U-8, as well as hard alloys. Furthermore, to increase the resistance of molds, the working parts were chrome-plated, nitrated, cemented, boronized, and thermally treated. Requirements on mold quality were developed with respect to their material, geometrical size tolerances, hardness, purity of working surfaces, etc.

However, the durability of molds in industrial conditions depends not only on the factors described but also on compliance with the operating regulations. Therefore, manuals for operation of molds were issued, which contributes to extending their service life.

Articles manufactured in the production division specified exhibited good service properties and high accuracy of geometric sizes and fully complied with requirements imposed.

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